Adventitious Rooting in 'Hopi' Sunflower: Function and Anatomy[1]

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ABSTRACT

The 'Hopi' sunflower (*Helianthus annuus* L.) is a primitive open-pollinated variety that produces numerous adventitious buds (nodules) on exposed lower stalks under greenhouse conditions. Similar conditions do not induce such budding in more advanced hybrids. The root buds remain dormant when exposed to air, but begin rapid growth into adventitious roots when covered with damp soil. Objectives of this study were to determine the effects of adding basal soil around stalks of Hopi and hybrid '894' sunflower on adventitious root development, contribution of the roots to plant standability, and anatomy of the roots. The addition of one or two 100-mm layers of soil around lower stalks induced significantly more (1% level) adventitious root growth above the original soil level on stalks of Hopi variety than on hybrid 894 stalks. When the addition of soil was delayed until plants were flowering, extensive adventitious rooting still occurred in Hopi sunflower, but little occurred in hybrid 894. Applying horizontal forces to stalks 0.3 and 0.6 m above the original soil level caused significantly less stalk deflection in Hopi than in hybrid 894 plants. The greater resistance to stalk deflection in Hopi was attributed to greater plant stability furnished by more extensive adventitious rooting. Anatomical studies revealed that the internal anatomy of adventitious roots was nearly identical to the internal anatomy of primary roots for both Hopi and hybrid 894. Roots of hybrid 894 had larger intercellular spaces in the cortex and a higher xylem to cortex ratio than comparable roots of the Hopi variety.

***Additional index words:* *Helianthus annuus* L., Drought resistance, Plant stability, Cropping practices, Compositeae.**

ADVENTITIOUS roots are distinguished from primary roots by their origin. Primary roots originate from the root pole of the embryo, whereas adventitious roots originate endogenously or develop in the vicinity of vascular tissue on aerial and underground stems and on old roots of plants (Esau, 1965). Adventitious roots may be complementary to primary root systems and may function in plant anchorage and in water absorption and conduction. The entire root systems of corn (*Zea mays* L.), other grain crops, and most grasses are essentially adventitious and conductive (Luxova and Kozinka, 1970; Taylor and Klepper, 1978). Many species of dicots also produce adventitious roots but their function is less clear than in monocots (Esau, 1965). Several studies have dealt with the role of flooding in inducing adventitious rooting in cultivated sunflower (*Helianthus annuus* L.) (Jackson, 1955; Kawase, 1972; Kawase and Whitmoyer, 1980; Kramer, 1951; Phillips, 1964; Stevenson and Boersma, 1964a, 1964b; Wample and Reid, 1975, 1978). Most of these studies dealt with the deleterious effects of flooding on sunflower associated with the development of adventitious roots.

The 'Hopi' sunflower is a primitive open-pollinated variety that originated and continues to be cultivated by the Hopi Indian Tribe in the semiarid southwest (Nabhan, 1979). It produces dormant adventitious root buds (or nodules) under greenhouse conditions. Several other primitive, cultivated sunflower varieties (Stevenson and Boersma, 1964a, 1964b; Wample and Reid, 1975, 1978); some primitive breeding lines; and some wild *Helianthus* species [e.g., *H. niveus* spp. *tephrodes* (Gray) Heiser] also produce the adventitious root buds under greenhouse conditions. Similar conditions do not induce such budding in more advanced hybrids or breeding lines. For example, in an earlier greenhouse test, Hopi plants had an average of 37.1 ± 4.7 adventitious root buds on the lower stalks (Fig. 1), while adjacent hybrid '894' (cms HA 89 × RHA

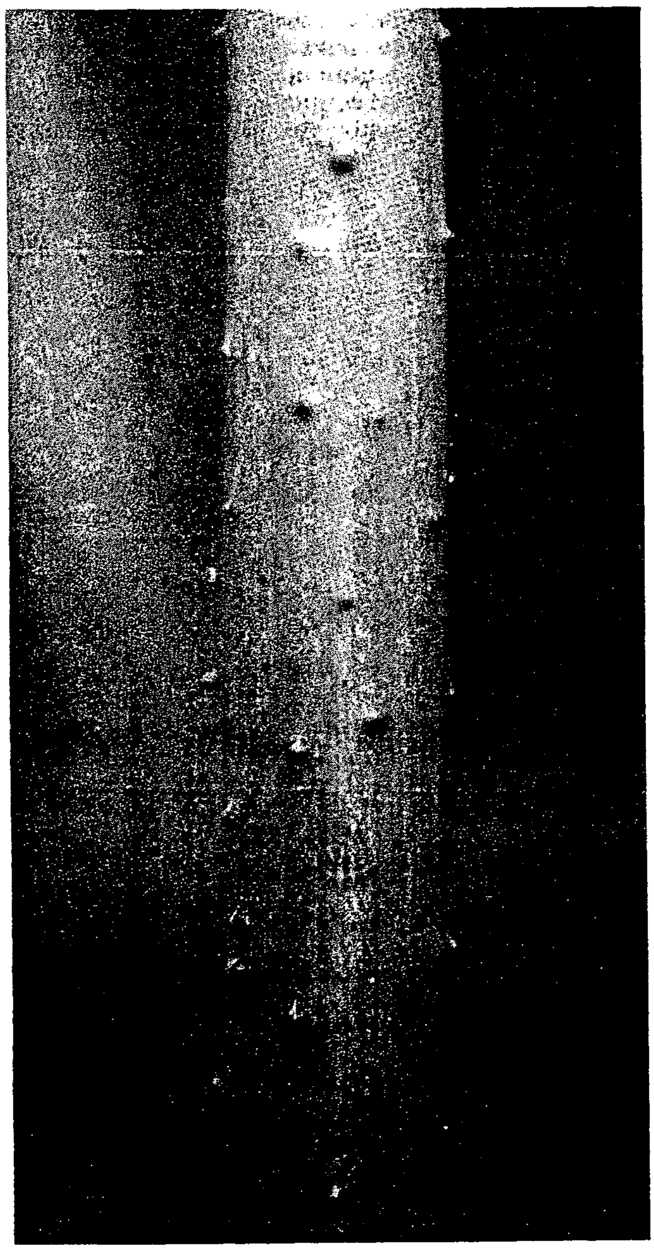

Fig. 1. Adventitious root buds (nodules) on exposed lower stalk of the 'Hopi' sunflower in the greenhouse.

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274) plants had an average of 1.4 ± 0.4 buds (Fig. 2). Of the plants examined, a Hopi plant had a maximum of 86 adventitious root buds compared with a maximum of three on a hybrid 894 plant (unpublished data). Also, in furrow-irrigated field plots at Bushland, Tex., in the summer of 1980, 85% of Hopi plants contained adventitious root buds on the lower stalks, compared with only 5% for hybrid 894. Hence, it appears that the expression of adventitious rooting in sunflower has a genetic basis, as well as being environmentally induced as earlier reported (Jackson, 1955; Phillips, 1964; Stevenson and Boersma, 1964a). Adventitious root buds apparently remain dormant in sunflower when exposed to the air. However, once the buds become covered with moistened soil, adventitious root growth commences and proceeds rather rapidly, resulting in extensive rooting above the original soil layer (Fig. 3). The objective of this research was to study the effect of adding basal soil to stalks of Hopi and hybrid 894 sunflower on (1) adventitious root development, (2) the contribution of adventitious roots to plant standability, and (3) the anatomy of adventitious roots.

MATERIALS AND METHODS

Seed of Hopi and hybrid 894 sunflower were planted in 0.31-m diam greenhouse pots containing about 9.5 kg of air-dry soil obtained from the surface horizon of Pullman clay loam (fine, mixed, thermic Torrertic Paleustolls). The pots were arranged in two rows in large greenhouse pans that provided uniform water absorption from the bottom of the pots as water was added to the pans. Water was added as needed to maintain vigorous plant growth. Hybrid 894 and Hopi sunflower were kept in separate pans to prevent excessive shading of hybrid 894 by the faster-growing, taller Hopi plants. Otherwise, all plants were handled uniformly throughout the study. After becoming established, the plants were thinned to one plant/pot, and randomly assigned soil-addition treatments. Within cultivars, plants for treatment were selected for uniformity of seedling vigor from a larger group of plants.

Fig. 2. Lower stalk of hybrid '894' sunflower lacking adventitious root buds under greenhouse conditions that induced budding on 'Hopi' sunflower shown in Fig. 1.

To study the development of adventitious roots, various quantities of soil were placed around the base of plants at different stages of development. Soil treatments began on Day 44 after planting when the Hopi plants averaged 0.75 m tall and hybrid 894 plants averaged 0.55 m tall. Treatments were: (1) no soil added (check), (2) 100 mm soil added on Day 44, (3) 200 mm soil added on Day 44, (4) 100 mm soil added on Day 44 and an additional 100 mm soil added on Day 58, (5) 100 mm soil added on Day 58, (6) 200 mm soil added on Day 58, and (7) 200 mm soil added at the start of anthesis, which was Day 77 for hybrid 894 and Day 94 for Hopi. The additional soil was placed within open-ended tar paper cylinders (300 mm in diameter and tall enough to contain the added soil) resting on the original soil surface apposed to the inner surface of pot rims. Treatments were replicated twice for hybrid 894 and three times for Hopi.

At physiological maturity (golden-yellow receptacles with bracts turning brown) (Schneiter and Miller, 1981), plants were decapitated to about 1 m above the initial soil level for ease of handling. To estimate the effects of adventitious roots on plant standability, stalk deflections caused by horizontal forces of 0.45, 0.91, 1.4, 1.8, and 2.3 kg were measured. Force was applied against the stalks by a push-pull gauge at 0.3 and 0.6 m above the initial soil surface. At each height, the respective force was applied in turn from three directions.

Following the deflection measurements, soil was washed from the roots of each plant. Primary root length was measured, and the number of adventitious roots produced in each soil layer was counted. Roots were removed and oven-dried at 70°C for 24 h to determine the dry weight for roots developed in the different soil layers.

Internal anatomy of primary and adventitious roots was studied by removing primary rootlets and adventitious roots from Hopi and hybrid 894 prior to drying and preparing them for microscopic anatomical examination. The roots were kept moist with wet paper towels until short, cylindrical sections of the roots were removed and fixed in a 4% solution of cacodylate buffered glutaraldehyde, followed with buffer rinses and postosmification in 2% cacodylate buffered osmium tetroxide. Dehydrated root pieces were embedded in plastic resin, serially sectioned with glass knives in an ultratome at 1 to 2 μm, and stained with toluidine blue for light microscopic observation.

Data for plant and rooting characteristics were analyzed by an analysis of variance and significantly different means within a cultivar were separated by Duncan's Multiple Range Test. Treatment means for the cultivars were compared by a paired *t*-test. Associations of stalk deflections due to a horizontal force and stem and root factors were analyzed by the multiple linear regression technique (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Data regarding effects of soil coverage on adventitious root growth in greenhouse-cultured sunflower are summarized in Table 1. As expected, adventitious roots did not develop in either cultivar where no soil was added subsequent to plant emergence. Also, the addition of soil following plant emergence had no sig-